

Home range of female sika deer *Cervus nippon* on Nozaki Island, the Goto Archipelago, Japan

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Abstract. The home ranges and habitat preferences of female sika deer (*Cervus nippon*) on Nozaki Island, in the Goto Archipelago were studied by radio-tracking. Six radio-tagged females were tracked continuously during June, August, October and December 1991. Female deer remained in small home ranges including both open and forest habitats throughout the year. These ranges overlapped to a considerable extent, however, individuals moved independently of each other. The females tended to select open habitats from spring to autumn and forest habitats in winter.

Key words: dynamic interaction, female sika deer, habitat preference, home range, radio-tracking.

Among the Cervidae, intraspecific variation in social systems has been found in species which have extensive geographical distributions. This has previously been discussed in the context of the differences in their habitat preferences (Langbein and Thirgood 1989). The sika deer (*Cervus nippon*) occurs very widely in Japan, from the cool temperate zone of Hokkaido in the north to the subtropical zone in the Nansei Shoto in the south, and exhibits considerable clinal variation in body size from north to south (Ohtaishi 1986). Intraspecific variation in male mating tactics have also been among populations of sika deer (Miura 1986). According to Davies (1991), it is likely that the variation in spatio-temporal dispersion of female sika deer may affect the intraspecific variation in male mating tactics. Many previous studies have reported on female home ranges in the cooler northern and central parts of Japan (Miura 1977, Maruyama 1981, Shigematsu *et al.* 1994, Yabe 1994), but none have been made so far in the warm temperate zone of southern Japan.

In the present study, we describe the seasonal changes in size and spacing patterns of home ranges, and the "dynamic interaction" (Macdonald *et al.* 1980) between individual female sika deer on Nozaki Island, in the Goto Archipelago.

STUDY AREA

Nozaki Island is a small (740 ha) island situated in the Goto Archipelago, west of Nagasaki Prefecture (33°10'N, 129°8'E), Kyushu. Most of the island is

covered with secondary evergreen broad-leaved forests dominated by *Castanopsis cuspidata*, *Camellia japonica* and *Machilus thunbergii*. The remainder is covered with young plantations of *Pinus thunbergii*, bushes of *Glochidion obovatum* or semi-natural *Miscanthus sinensis*, *Imperata slyndorica* and *Zoysia japonica* grasslands (Kawahara 1983). About 700 deer live on the island (Doi and Endo 1992), varying in density from 0.6/ha in forest to 3.1/ha in open grassland. No hunting or predation occurred during the study period. Home ranges of female sika deer were studied at the Nozaki site (about 30 ha) in the central part of the island, where the density of deer was highest. About 40 females utilized this area.

METHODS

In 1991, we captured six female deer using bag net traps (Doi *et al.* 1986) and attached radio neck-collars (50MHz, weight 50 g, ALKITEC Co. Ltd.). Radio-fixes on females were obtained by triangulation with a portable receiver (FT-690, YAESU MUSEN Co. Ltd.), and one or two additional fixes were regularly taken from other points to ensure accuracy. Radio-fixes, dates and times were all plotted on a 1 : 2500 map. Tracking in 1991 was carried out in June (early summer, parturition season), August (mid-summer, milking-season), October (autumm, rutting season) and December (winter). Tagged deer were radio-fixed at three hour intervals for several days. Since cumulative home range sizes were saturated by the fourth to seventh day, tracking was terminated on the seventh day. The radio-collar on deer F1 fell off before December 1991, thus data was only collected for deer F2 to F6 during December. The home range sizes were calculated using the convex polygon method (Mohr 1947). Seasonal shifts in range use were expressed by the degrees of range overlap (*RO*) between two seasons. It was calculated as :

$$RO = \frac{\text{size of range overlap between two months (ha)}}{\text{home range size (ha)}}$$

The percentage overlap of two home ranges is most useful for identifying spatial distribution (Macdonald *et al.* 1980). It does not, however, indicate the utilization distribution within the shared parts of overlapping ranges (Doncaster 1990). This aspect can be elucidated by testing for the dependency in the simultaneous movements of a pair of individuals (dynamic interaction). Analyses of dynamic interactions between females indicate whether two females are more (positive dynamic interaction) or less (negative dynamic interaction) likely to maintain a certain separation given the configuration and utilization of their home ranges (Doncaster 1990). To test dynamic interaction, a nonparametric comparison was made between the observed distribution of separations between *N* paired fixes (taken from each animal simultaneously or within 30 minutes of each other), and an expected distribution based on all possible combinations (*N*²) of the fixes (Doncaster 1990). A critical separation is chosen within which presence of dynamic interaction is of interest, such as

the furthest separation at which two females could be aware of each other. Since we have no information about the sensitive distance for sika deer, we determined the critical separation as 20 m based on observations of white-tailed deer (*Odocoileus virginianus*, Schwede *et al.* 1993). Expected and observed numbers of paired separations <20 m were compared using the χ^2 - test ($p < 0.05$). When observed numbers of paired separations <20 m was significantly greater than expected, it indicates that those individuals tended to move simultaneously.

In examining habitat preference, the study area was classified into forest and open habitat types. "Forest" includes secondary evergreen broad-leaved forests and young pine plantations in old crop fields, and "open" includes young *Glochidion obovatum* bushes in old crop fields, and grasslands dominated by *Zoysia japonica* in old crop fields and abandoned rice fields.

Habitat selection was expressed by Ivlev's electivity index (E_i ; Ivlev 1961). This index was calculated as :

$$E_i = (r_i - N_i) / (r_i + N_i)$$

where r_i is the proportion of the size of the i th habitat type to home range size in each season, and N_i is the proportion of the size of the i th habitat type to the annual home range size.

RESULTS

1. Size and Spatial Distribution of Female Home Ranges

Mean home range sizes ranged from 3.0 to 3.6 ha, and were not significantly different between seasons (Friedman's test : $\chi^2 = 0.360$, $p = 0.948$, see Table 1). Ranges did not shift seasonally (Fig. 1). The rate of overlap was more than 0.5 and there was no significant difference between seasons (Friedman's test : $\chi^2 = 9.4$, $p = 0.585$, Table 2).

Table 1. Seasonal changes in home range size of female sika deer on Nozaki Island. Number of females shown in parenthesis.

Month	Home range size(ha) Mean \pm SD (N)
Jun.	3.47 \pm 0.57 (6)
Aug.	3.27 \pm 1.25 (6)
Oct.	3.03 \pm 0.99 (6)
Dec.	3.60 \pm 0.33 (5) *

*radio-collar of F1 fell off before December 1991.

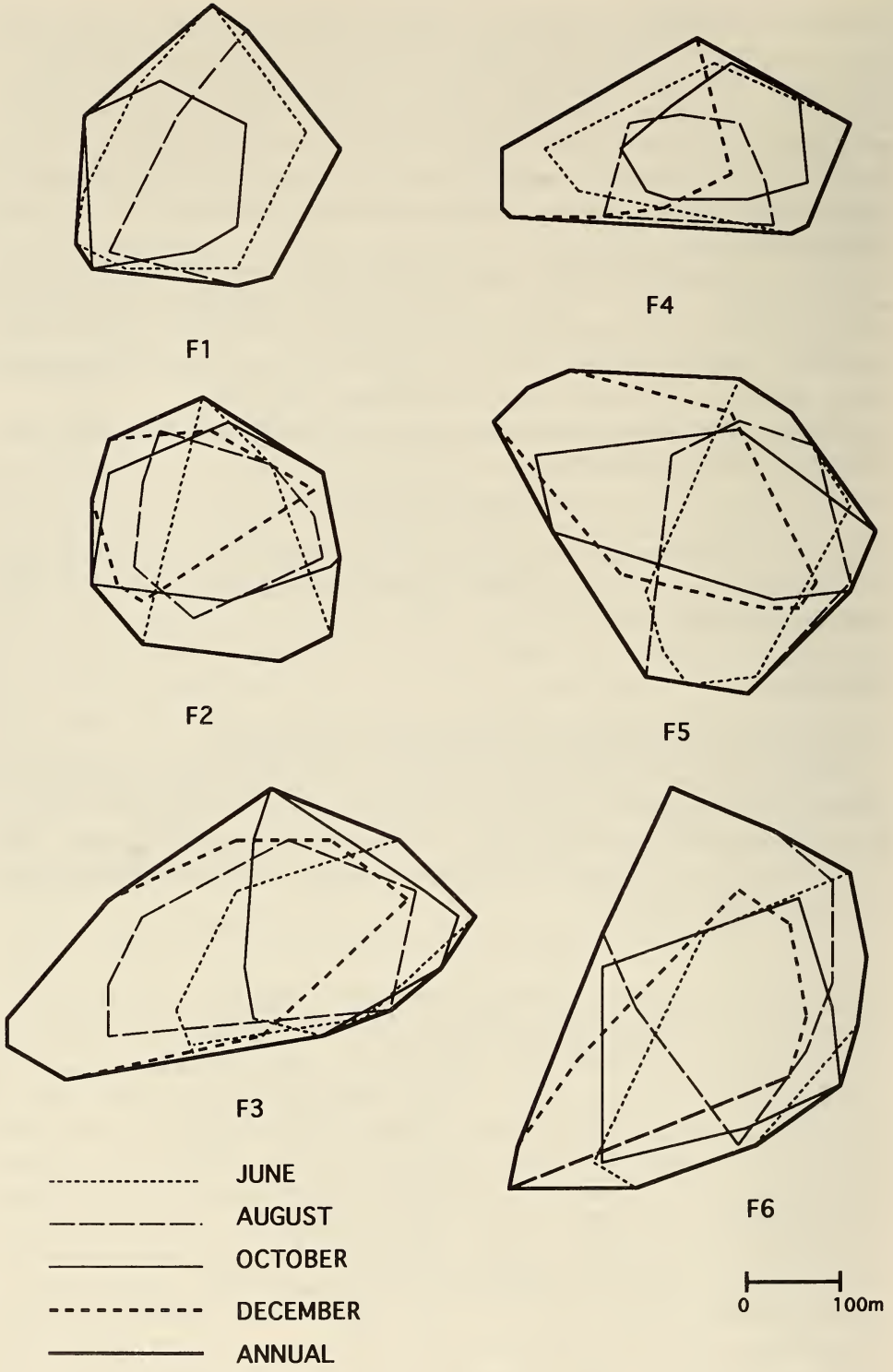


Fig. 1. Home ranges of six female sika deer (F1-F6).

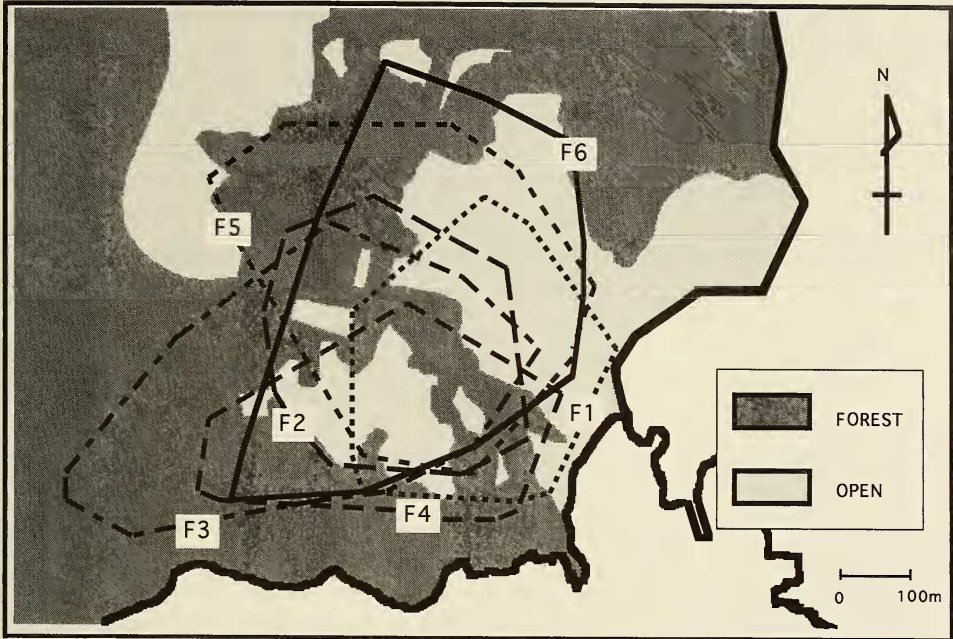


Fig. 2. Annual home ranges of six female sika deer (F1-F6) in relation to habitat type.

2. Dynamic Interactions of Females

Annual home ranges were found to overlap considerably with each other (Fig. 2), suggesting that females permit each other to enter their own ranges, and that they form home range groups (Miura 1976). To evaluate the dependency in the simultaneous movements of pairs of females, we analyzed dynamic interactions among them (Table 3). Paired separations of less than 20 m were less frequent than those of more than 20 m for all dyads. Expected and observed number of paired separations <20 m were not significantly different except in one case (Table 3). In this case, only 4 out of 114 (3.5%) observed separations were < 20 m, thus evidence of dynamic interactions was limited to just two specific females. Generally, however, there was no dependency in the simultaneous movements of pairs of females, even though their home ranges overlapped.

Table 2. Degrees of range overlaps (*RO*) of female sika deer between seasons. *RO* was calculated as: size of overlap between two months (ha) / home range size (ha). Numbers of females are shown in parenthesis.

Jun.--Aug.	Jun.--Oct.	Jun.--Dec.	Jun.--Oct.	Aug.--Oct.	Oct.--Dec.
Jun.	Jun.	Jun.	Oct.	Oct.	Oct.
0.66±0.19 (N=6)	0.63±0.11 (N=6)	0.51±0.11 (N=5)	0.72±0.19 (N=6)	0.64±0.07 (N=6)	0.61±0.13 (N=5)
Jun.--Aug.	Aug.--Oct.	Aug.--Dec.	Jun.--Dec.	Aug.--Dec.	Oct.--Dec.
Aug.	Aug.	Aug.	Dec.	Dec.	Dec.
0.73±0.14 (N=6)	0.66±0.16 (N=6)	0.60±0.15 (N=5)	0.51±0.13 (N=5)	0.54±0.14 (N=5)	0.59±0.27 (N=5)

Tabl 3. Frequencies of N paired and N²-N unpaired distances, and those below and over the critical distance of 20 m. n.s. : non-significant.

		F2		F3		F4		F5		F6	
		<20m	20m≤	<20m	20m≤	<20m	20m≤	<20m	20m≤	<20m	20m≤
F1	Paired	4	116	4	112	8	120	6	100	5	99
	Unpaired	452	13828	356	12984	586	15670	324	10806	391	10321
		$\chi^2=0, n.s.$		$\chi^2=.053, n.s.$		$\chi^2=1.84, n.s.$		$\chi^2=1.90, n.s.$		$\chi^2=.132, n.s.$	
F2	Paired			1	132	3	141	6	121	2	123
	Unpaired			309	17247	300	20292	332	15670	301	15199
				$\chi^2=.30, n.s.$		$\chi^2=.076, n.s.$		$\chi^2=3.12, n.s.$		$\chi^2=0, n.s.$	
F3	Paired					9	132	4	110	3	109
	Unpaired					668	19072	116	12766	147	12285
						$\chi^2=2.97, n.s.$		$\chi^2=5.794, p<0.05$		$\chi^2=1.027, n.s.$	
F4	Paired							2	116	2	122
	Unpaired							147	13659	158	15094
								$\chi^2=.045, n.s.$		$\chi^2=.035, n.s.$	
F5	Paired									7	114
	Unpaired									396	14124
										$\chi^2=3.127, n.s.$	

3. Habitat Preference

Home ranges of female deer included both forest and open habitats. The seasonal changes of habitat preference for forest and open habitats were expressed by the electivity index (E_i)(Fig. 3). E_i for open habitats were positive

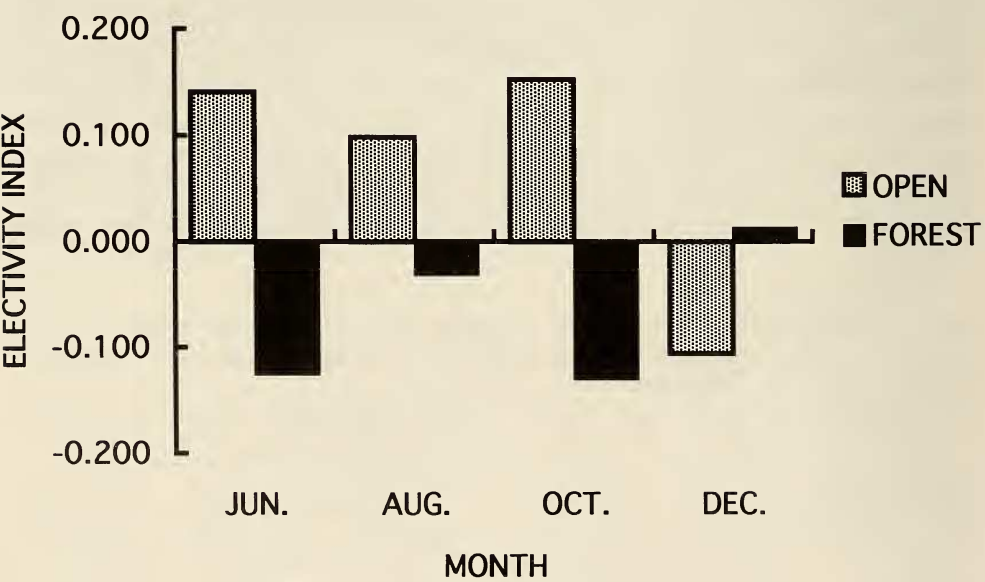


Fig. 3. The seasonal changes in habitat preferences.

from June to October, but significantly negative in December (Friedman's test: $\chi^2=10.680$, $p<0.05$). In contrast, E_i for forests was negative from June to October and positive in December, though they were not significantly different (Friedman's test: $\chi^2=7.800$, $p>0.05$). E_i for open habitat was significantly positive in June (Student's t -test, $t=3.069$, $p<0.05$), while it was significantly negative in October ($t=3.088$, $p<0.05$). They were not significant in August ($t=2.248$, $p=0.0745$) and December ($t=-1.895$, $p>0.05$). These results indicate that the females preferred open habitats from June to October and forest habitats in December.

DISCUSSION

Previous studies on the home ranges of sika deer have been made mainly on populations in the northern and central parts of Japan (Miura 1977, Maruyama 1981, Shigematsu *et al.* 1994, Yabe 1994). This is the first study from southern Japan. The mean size of the annual home ranges of resident females in the Hokkaido population was 325.2 ha (Yabe 1994). In Nikko in central Japan, the monthly home range sizes of males and females varied from 21.0 to 284 ha (Maruyama 1981), and in Chiba Prefecture, the female annual home ranges varied from 46.1 to 246.3 ha (Shigematsu *et al.* 1994). For the Nara population, the mean summer home range was 11.7 ha (Miura 1977). Compared to these results, the home ranges of the Nozaki population were considerably smaller. This difference may result from four factors.

First, in the northern areas seasonal migration serves to enlarge home range size, as leaves fall in autumn reducing cover, and as snow cover reduces food availability in winter, deer are forced to move to lower altitudes (Maruyama *et al.* 1976, Maruyama 1981, Ito and Takatsuki 1987, Takatsuki 1992). On Nozaki Island, in contrast, warm temperature, lack of snow, and the presence of evergreen forests enable the deer to remain in one area all year without migrating.

Second, home range size is related to body size. In Hokkaido, adult females weighed about 75.0 kg (Kaji *et al.* 1988, Yabe 1994), on Mt. Goyo (Takatsuki 1992) and in Chiba about 45.0 kg (Shigematsu *et al.* 1994), whereas the mean body weight of females on Nozaki Island was considerably less at just 32.2 ± 1.6 (SD) kg ($N=6$). Even when the effect of migration was excluded, home range sizes varied among resident populations. Therefore, the small range size of females on Nozaki Island are a reflection of their smaller body weight.

Third, the type of vegetation affects home range size. For resident populations of sika deer, two types of home ranges (small stable type, and large) were reported in Chiba (Shigematsu *et al.* 1994) and in the Ashio population (Koganezawa and Satake, pers. comm.). The small stable type included *Zoysia*-type grasslands whereas the large type did not. Shigematsu *et al.* (1994) explained this variation by the presence of the highly productive *Zoysia*-type grasslands enabling the deer to thrive in smaller home ranges. Miyazaki

et al. (1977) suggested that highly productive *Zoysia*-type grasslands were also an important resource for the Nara deer population. On Nozaki Island, female home ranges also included *Zoysia*-type grasslands. The electivity index showed their high preference for open habitats in all seasons except winter (Fig. 3). It seems likely that the high productivity of *Zoysia*-type grassland facilitates the use of smaller home ranges by females in the Nozaki population.

Finally, deer density reached as high as 3.1/ha (Doi and Endo 1992) on Nozaki Island, which is higher than in other populations. Other studies of natural populations have reported highest densities as just 0.3/ha in Chiba (Ochiai and Asada 1993), 0.5/ha on Nakanoshima (Kaji *et al.* 1988), 0.6/ha on Kinkazan Island (Ito 1987) and 2.0/ha on Mt. Goyo (Takatsuki 1992). In addition to these four factors, spatial restriction on the island may also be an important factor affecting home range size.

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